[001] METHOD FOR CROSS-LINKING OF REGULATION-AND/OR CONTROL FUNCTIONS FOR A MOTOR VEHICLE

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[004] The present invention concerns a method for interlinking regulation and/or control functions in a motor vehicle, according to the preamble of Claim 1.

[005]

[006] Nowadays numerous different systems are incorporated in motor vehicles, and their number will increase as time goes by; examples of such systems are the electronic engine controls, the electronic transmission controls, the ASR (drive slip regulation) and ABS (anti-blocking system) functions, the shift strategy controls, the level adjustment, etc.

[007] In this, the situation can arise that the functions have a reciprocally negative influence on one another; furthermore, the allocation of control and regulation algorithms to functional modules often takes place unsystematically. This in turn means that an extension of the function structure is very time-consuming and expensive.

[008] Owing to the multiplicity of systems used, some of which act on the same vehicle components, for example comfort and driving stability functions which both influence the shock-absorbers, a defined optimum cooperation of these systems is necessary in order to ensure safe and comfortable driving behavior.

[009] From the prior art, methods or systems are known for the control and/or regulation of motor vehicle components. For example, in the context of DE 411 10 23 A1 a system is described, which consists of elements for carrying out control operations related at least to the engine output, the drive input power and the braking process, and elements that coordinate the cooperation of the said elements for carrying out control operations, the elements being arranged in the form of a hierarchy so that elements at one level of the hierarchy can act upon elements at the next level of the hierarchy.

[010] In addition, from DE 198 38 336 A1 a system for controlling the movement of a motor vehicle is known, which consists of several levels such that at least one component for controlling the vehicle's movement is provided at a first level, which as a refinement contains at least one positive drive component and brakes at a second level. Further, at a third level this component is structured into two individual components, drive and braking system. In this system, the components can communicate with one another to exchange information.

[011] Thus, in these known methods there is a rough structuring for functions of the drive train and braking system; the functional structure is organized as a tree structure, which restricts the cooperation of the functions, particularly in relation to the specification of required operating modes or nominal values.

[012] Furthermore, in the known approaches the structuring of control and/or regulation functions that act upon lower structural levels, and the details of the communication relationships between the functions, are not defined.

[013] The purpose of the present invention is to indicate a method for interlinking regulation and/or control functions in a motor vehicle, which avoids the disadvantages typical of the prior art.

[014] In particular the intention is to indicate a defined prescription for establishing a function and communication structure down to lower hierarchy levels. In addition the structure produced by the method should be interlinked in a failure-resistant manner, so that the control functions remain active when communication is defective or when other functions fail. A further aim is to enable easy extension to additional control and/or regulation functions, without modifying the existing structures.

[015] These objectives are achieved by the characteristics of Claim 1. Other variants and advantages emerge from the subordinate claims.

[016]

[017] According to these, it is proposed to define the distribution of the control and/or regulation functions and the communications structure of the control and/or regulation functions by means of graphs containing nodes and directed gridlines,

in which the nodes of the graphs represent control and/or regulation functions and the directed gridlines represent defined communication paths of the control and/or regulation functions.

[018] For a vehicle with a defined number of control intervention points involving corresponding actuators, for example level adjustment or service brakes, and a defined number of system parameters to be controlled or regulated, for example vehicle level or wheel slip, according to the invention the various control and regulation algorithms are distributed among various control and/or regulation functions and the communication of the control and/or regulation functions is defined.

[019] The method according to the invention ensures optimum system behavior in relation to safety, driving comfort and the driver's wishes in each case, in particular by virtue of the ordered interaction of the control and regulation algorithms.

[020]

[021] Below, an example of the invention is explained in greater detail with reference to the attached figures, which show:

[022] Fig. 1 is a schematic representation of two nodes and a directed gridline and the communication between the control and/or regulation functions involved, according to the present invention;

[023] Fig. 2 is a schematic representation of two nodes and a directed gridline and the communication between the control and/or regulation functions involved, in a direction opposite to the communication represented in Fig. 1, according to the present invention;

[024] Fig. 3 is an example embodiment of a table according to the present invention that can be used to plot a graph according to the invention;

[025] Fig. 4 is an example embodiment of another table according to the present invention that can be used to plot a graph according to the invention;

[026] Fig. 5 is a example of a graph plotted by means of the method according to the invention; and

[027] Fig. 6 is an example of another graph plotted by means of the method according to the invention.

[028]

[029] According to the invention, the distribution of the control and/or regulation functions of a motor vehicle and the communications structure of the control and/or regulation functions is defined by means of graphs containing nodes and directed gridlines; in this, the nodes of the graphs represent control and/or regulation functions and their directed gridlines represent transmission paths of the control and/or regulation functions.

[030] According to the invention the directed gridlines of the graphs connect ordered pairs (X, Y) of control and/or regulation functions and can be represented as arrows between the nodes, i.e. the functions. This is represented schematically in Figs. 1 and 2. A graph contains a finite number of nodes.

[031] According to the invention the nodes are defined as follows: they represent control or regulation functions G_i, R_i and S_i such that G_i is at least one function defined for each system parameter g_i to be controlled, which defines nominal values ${}^{soll}y_l$ for g_i, R_i is at least one function defined for each system parameter g_i to be controlled and/or regulated, which controls and/or regulates g_i by means of nominal values specified for other functions X_1, X_2, X_3 ..., and s_i is a function defined for each control intervention point S_i, which organizes the access of the functions X_1, X_2, X_3, ... to the control intervention point s_i. According to the invention only one node is defined for one function.

[032] According to the invention, instead of two functions G_i and G_j a single function G can define nominal values for the system parameters g_i and g_j or, instead of two functions R_i and R_j, a single function R can control the system parameters g_i and g_j, so that functions denoted in different ways such as X_i and X_j or S_i and S_j do not necessarily have to be separate functions but can also be amalgamated.

[033] For each function Z, according to the invention an actual operation mode parameter ${}^{ist}b_Z$ is defined, which can have for example the values "active",

"inactive", "limp home", etc. For this the actual operation mode ${}^{ist}b_z$ is calculated as follows:

- The function Z| obtains nominal operation modes ${}^{soll}b_{X1}$, ${}^{soll}b_{X2}$, ${}^{soll}b_{X3}$... ${}^{soll}b_{Xn}$ from n other functions X_1, X_2, X_3, ... X_n.
- The function Z obtains actual operation modes ${}^{ist}b_{Y1}$, ${}^{ist}b_{Y2,}$ ${}^{ist}b_{Y3}$, ... ${}^{ist}b_{Ym}$ from m other functions $Y_{1,}$ Y_2, $Y_{3,\dots}Y_m$.
- In addition, there is an internal nominal operation mode of the function Z ${}^{soll}b_{Zintern}$ (the internal nominal operation mode can for example indicate a fault mode of the function).
- The actual operation mode ${}^{ist}b_Z$ of the function Z is calculated by means of a function-specific function f:

$${}^{ist}b_Z = f\,({}^{soll}b_{X1},\ {}^{soll}b_{X2},\ {}^{soll}b_{X3},\ \dots\ {}^{soll}b_{Xn},\ {}^{ist}b_{Y1,}\ {}^{ist}b_{Y2},\ {}^{ist}b_{Y3},\ \dots {}^{ist}b_{Ym},\ {}^{soll}b_{Zintern}),$$

and for this the calculation can for example be carried out with the aid of access to a (n + m +1)-dimensional array:

$${}^{ist}b_z = \text{Array}\,({}^{soll}b_{X1},\ {}^{soll}b_{X2},\ {}^{soll}b_{X3},\ \dots\ {}^{soll}b_{Xn},\ {}^{ist}b_{Y1,}\ {}^{ist}b_{Y2},\ {}^{ist}b_{Y3},\ \dots,\ {}^{ist}b_{Ym},\ {}^{soll}b_{Zintern}).$$

[034] If the function Z receives no external operation mode, then the actual operation mode is calculated solely on the basis of the internal nominal operation mode: ${}^{ist}b_Z = {}^{soll}b_{Zintern}$; transmission of a fault mode to other functions takes place by means of the actual operation mode ${}^{ist}b_Z$.

[035] For two nodes X and Y the directed gridline (X, Y) is then actually plotted on the graphs when the function X transmits a nominal operation mode to the function Y (Fig. 1). When the gridline (X, Y) is in place, then the function X can optionally transmit to the function Y one or more nominal values α, ß, χ, ... for system or control parameters a, b, c, etc.

[036] In addition, when (X, Y) is a gridline in the graph, the function Y must transmit precisely one actual operation condition ${}^{ist}b_Y$ to the function X, as shown in Fig. 2. If X, Y is a gridline in the graph, then the function Y can optionally transmit to the function X one or more nominal values λ, μ, ν, ... for system or control parameters l, m, n, ... as illustrated in Fig. 2.

[037] By virtue of the actual operation condition ${}^{ist}b_Y$ the function X can for example evaluate whether the function Y is implementing the specification of the nominal operation mode and perhaps the nominal values. If the function Y is not implementing the specifications to a sufficient extent, then according to the invention the function X must look for alternatives for the implementation of the target specifications. For example, targets of the function X could be realized with the help of other functions Y_2, Y_3, Y_4, ...; it can also be provided that the function X reacts with a change of its own operation mode.

[038] According to the invention, when (X, Y) is an gridline in the graph, the function Y can transmit to the function X optional limits α_{min}, α_{max}, β_{min}, β_{max}, χ_{min}, χ_{max}, ... within which the function Y can realize nominal value specifications for system or control parameters a, b, c, ... In this way the function X can test the practicability of its nominal value specifications by the function Y and if necessary activate further functions Y_2, Y_3, Y_4, ...

[039] Although with a directed gridline (X, Y) the function Y does not transmit any nominal operation mode to the function X, by transmitting nominal values to the function X, the function Y can influence X so as to realize the target specifications of Y. Sometimes the function X will have to pass on the nominal values to other functions. For example, resources (for example in relation to energy supply) can be called for. Besides, a function X can transmit actual system parameters to a function Y without the gridline (X, Y) being defined in the graph; for example, this can be the case with sensor values.

[040] When several functions X_1, X_2, X_3, ... transmit nominal values ${}^{soll}w_{X1}$, ${}^{soll}w_{X2}$, ${}^{soll}w_{X3}$, ... for a parameter w to the function Y, then according to the invention access conflicts are prevented as follows:

[041] Depending on the actual operation mode ${}^{ist}b_Y$ of the function Y, the function Y decides which of the nominal values ${}^{soll}w_{X1}$, ${}^{soll}w_{X2}$, ${}^{soll}w_{X3}$, ... will be used or how the nominal value to be used for the parameter w is to be calculated from ${}^{soll}w_{X1}$, ${}^{soll}w_{X2}$, ${}^{soll}w_{X3}$, ... In addition, the calculation of the actual operation mode by means of nominal or actual operation modes is carried out in such

manner that a clear selection or calculation of the nominal value for w emerges from the quantity of the nominal values $\{{}^{soll}w_{X1}, {}^{soll}w_{X2}, {}^{soll}w_{X3}, \ldots\}$.

[042] Alternatively, the decision which of the nominal values $\{{}^{soll}w_{X1}, {}^{soll}w_{X2}, {}^{soll}w_{X3}, \ldots\}$ or which calculation method should be used can be specified by a defined function Z where $Z \notin \{X_i\}$ and $Z \neq Y$, so that in this case the function Z transmits an operation mode ${}^{soll}b_Z$ to the function Y so that the calculation of the internal actual operation mode ${}^{ist}b_Y$ and thus the selection of a nominal value or a calculation method takes place in such manner that the nominal value or the calculation method of the nominal value for w depends only on ${}^{soll}b_Z$.

[043] Thus, the nominal operation modes regulate the cooperation of the control functions in a clear and deterministic way.

[044] According to the invention the gridlines of the graphs are so chosen that no directed cycle is produced. This means that a function cannot indirectly specify an operation mode for itself along a communication chain X_1 - X_2 - X_3 - ... X_n - X_1. For example, according to the invention it is not possible that both (X, Y) and (Y, X) are directed gridlines in the graph, since this would produce a directed cycle X - Y - X.

[045] According to the invention, the directed gridlines of a graph can for example be determined by the following process:

[046] A first table is prepared according to Fig. 3, in the first column of which the functions G_i and in the first row of which the functions R_i are entered, so that cells (G_i, R_i) are produced. When G_i defines a nominal value for g_i, then a cross "x" is inserted in the cell (G_i, R_i) of the table or the said cell (G_i, R_i) is marked.

[047] Then, a second table according to Fig. 4 is prepared, in whose first row the functions s_i and in whose first column the functions R_i are entered. When the control parameter s_i affects the system parameter g_j and the function R_i uses the function s_i for the control and/or regulation of g_j, then a cross "x" is inserted in cell (R_i, S_j) of the table (or the cell (R_i, S_j) is marked).

[048] According to the invention, the cells marked with "x" in the tables are the necessary gridlines of the associated graph, which is the object of Fig. 5.

[049] The invention will now be described in more detail with reference to an example application.

[050] The control interventions

- s_1 variable damping,
- s_2 stabilizer torque,
- s_3 level regulation and
- s_4 engine torque

and the corresponding functions s_1, s_2, s_3 and s_4 are defined. In this, to simplify the representation of the example application the control interventions on control parameters of the same type are summarized as one control intervention. For example, the damping interventions on individual wheels are summarized as one control intervention s_1, for simplicity. As system parameters

- g_1 body – vertical acceleration,
- g_2 roll angle,
- g_3 pitch angle,
- g_4 vehicle level and
- g_5 wheel slip

and the corresponding functions G_1, G_2, G_3, G_4 and G_5 are defined. In this, G_1 defines a nominal value ${}^{sol}y_1$ for the vertical acceleration, G_2 a nominal value ${}^{soll}y_2$ for the roll angle, G_3 a nominal value ${}^{soll}y_3$ for the pitch angle, G_4 a nominal value ${}^{soll}y_4$ for the vehicle level and G_5 a nominal value ${}^{soll}y_5$ for the wheel slip. In addition, the functions R_1 control/regulation of body vertical acceleration, R_2 control/regulation of roll angle, R_3 control/regulation of pitch angle, R_4 level regulation and R_5 wheel slip regulation are defined.

[051] According to the table shown in Fig. 3, for example between $\{G_i\}$ and $\{R_i\}$ the following directed gridlines are determined:

$$(G_1, R_1),\ (G_2, R_2),\ (G_3, R_3),\ (G_4, R_4),\ (G_5, R_5)$$

The directed gridlines between the functions $\{R_i\}$ and $\{S_i\}$ can be seen in the table of Fig. 4:

(P_1, S_1), (R_2, S_1), $(R_3. S_1)$, (R_2, S_2), (R_5, S_2), (R_4, S_3), (R_5, S_4)

For example the gridline (R_5, S_4) allows for the possibility that a function R_5, which regulates the wheel slip, intervenes directly in the stabilizer in safety-critical driving situations, in order to obtain a corresponding wheel load.

[052] As the outcome of the method for interlinking regulation and/or control functions, the graph in Fig. 5 is obtained. This functional structure cannot be represented in the form of a tree.

[053] As already mentioned, functions can be combined. For example, if G_1, G_2 and G_3 are combined as one function G, the graph shown in Fig. 6 is produced.